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# **PORTABLE NONDESTRUCTIVE TESTING AND DYNAMIC TEST DIAGNOSTICS AT LOS ALAMOS NATIONAL LABORATORY**

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## **INTRODUCTION**

Los Alamos National Laboratory maintains one of the most complete NDT facilities worldwide. In addition to many fixed pieces of equipment, the Laboratory has a very wide range of NDT and dynamic test diagnostic equipment that can be taken to the job site. Most of the equipment described here was procured for a specific purpose to support a program consistent with the nuclear weapons mission of Los Alamos. However, through the years, the equipment has found use in many other applications both within and external to weapons research, development, and testing. Various combinations of these equipments form unique capabilities, as demonstrated by the applications. The portable equipment is mainly applied to problems where the process or object under study cannot be brought into an NDT laboratory.

## **EQUIPMENT**

### **Fixed Equipment**

Fixed equipment is listed here because many times portable x-ray imaging equipment is moved to the x-ray bays or large flash x-ray devices to create a unique technique. It is also listed to show the diverse and complementary range of NDT that can be performed on site.

- 5 to 50 kVp Balteau X-ray, 750 W, Helium atmosphere
- 10 to 50 kVp Balteau X-ray, 1 kW
- 10 to 160 kVp Philips X-ray, 3 kW
- 20 to 180 kVp Scanray Microfocus X-ray, 400 W
- 20 to 275 kVp Triplett & Barton X-ray, 2.75 kW
- 20 to 300 kVp Norelco X-ray, 3kW
- 20 to 320 kVp Philips X-ray, 3 kW
- 1.5 to 2.5 MV Van de Graaff, 150 R/min @ 1 m
- 23 MV Allis-Chalmers Betatron, 125 R/min @ 1 m
- (5-10-15-20 MV Scanditronix Microtron - will replace Betatron in 1995)
- 320 kVp based Computed Tomography
- PIXY, single 60 nsec pulse, 6 MV, 100 R/pulse @ 1 m
- ECTOR, single 60 nsec pulse, 4 MV, 30 R/pulse @ 1 m
- PHERMEX, single 200 nsec pulse, 25 MV, 150 R/pulse @ 1 m

- Ultrasonic Microscope, 2 axis scanning, 50 Mhz, up to 10"x10"x5"
- Cylindrical/Spherical Ultrasonic Scanner, 4 axis scanning, 25 Mhz, up to 12" diameter
- Magnetic Particle Station, up to 12" diameter x 10 feet
- Penetrant Station, 3 - 1 ft x 6 ft x 3 ft tanks
- Super-VHS Video Editing Suite

### **Portable Low/Medium Energy X-ray Machines**

The low and medium energy x-ray machines cover the range 10 to 420 kVp. The Sperry units are high frequency (900 hz) and therefore well suited to standard video RTR and high speed x-ray video. The Philips 420 kVp unit is available to us through Sandia National Laboratories at Albuquerque (100 miles from Los Alamos). It is a constant potential unit utilizing low weight gas insulated transformers - less than 100 lbs. each.

- 10 to 160 kVp Sperry X-ray (2 units), 3 kW
- 10 to 300 kVp Sperry X-ray, 3 kW
- 20 to 420 kVp Philips X-ray (Sandia National Laboratories), 4 kW

### **Portable Linear Accelerators**

We own two portable linacs, each having their good and bad points. The Schonberg unit has a very small x-ray head excellent for positioning in unusual situations. The L&W unit is very reliable and environmentally sealed to operate in all weather conditions and temperatures from -40°F to +120°F.

- 6 MV Schonberg Minac-6, 0 to 130 R/min @ 1 m
- 6 MV L&W Research Portac-6, 15 to 300 R/min @ 1 m

### **Portable Cobalt-60**

A Co-60 shield/projector is mounted on a gasoline powered hand-driven tracked vehicle for easy movement in all terrain. It provides highly mobile, high energy radiography source.

- up to 300 Ci Co-60 mounted on hand tractor

### **Portable Real-Time Radiography**

Three x-ray image intensifiers (XRIs) and two portable racks of video image processing equipment enable state-of-the-art RTR anywhere. The video equipment racks have processing, recording, and hard copy printing capability. The racks are mountable in the Vans listed below.

- 9 inch XRII, tri-field
- 12 inch XRII, tri-field
- 16 inch XRII, tri-field
- CCD, CID, SIT and Newvicon video cameras
- Processing Rack A:
  - Quantel Sapphire Computer
  - Bernoulli Box Disk Drive
  - S-VHS VCR
  - Codonics VP-3500 Video Printer
- Processing Rack B:
  - LKH-2000 Computer with Removable PCMCIA Disk Drives
  - S-VHS VCR
  - Sony UP-7000 Video Printer
  - X-ray Image Intensifier Controller

### **High Speed Video**

The high speed video systems can be used to directly view an event or view the output of an x-ray image intensifier to record high speed x-ray video. Los Alamos is one of few if not the only organization performing high speed x-ray video. The EktaPro is a recently acquired device. It is all digital, able to record and play back 1024 images in solid state memory.

- Spin Physics SP-2000, up to 2000 full frames/sec @ 240x192 resolution, 12000 split frames/sec @ 240x32 resolution
- EktaPro HS4540, up to 4500 full frames/sec @ 256x256 resolution, 40500 frames/sec @ 64x64 resolution

### **Electronic Imaging**

We have used our single shot video cameras as electronic x-ray imagers in the place of film to create special effects - see Applications section: Missile Stage Separation Testing and Flash X-ray with Electronic Imaging headings. The Kodak still video operates like a standard SLR camera but produces photographs on a CCD sensor which are digitized and stored to an on-board hard disk for later retrieval by a computer.

- Xybion single shot intensified video cameras (4 units), 100 nsec minimum exposure, 377x242
- Hadland Photonics SV-553BR single shot intensified video cameras (6 units), 250 nsec minimum exposure, 1134x486
- Kodak DCS200 Still Video Camera, 1524x1012 CCD in Nikon 8008s body, 80 Mbyte on-board hard disk with 50 image capacity

### **Portable Flash X-ray**

The flash x-ray units are very versatile and mobile and have been extremely well used at all Los Alamos firing sites. Their application to other fast moving events such as crash testing is currently under evaluation.

- 180 kVp Hewlett-Packard (2 units), 1.6 mR/pulse @ 1 m, 50 nsec/pulse
- 300 kVp Hewlett-Packard (1 unit), 7 mR/pulse @ 1 m, 50 nsec/pulse
- 450 kVp Hewlett-Packard (2 units), 20 mR/pulse @ 1 m, 25 nsec/pulse
- 1 MV Hewlett-Packard (6 units), 55 mR/pulse @ 1 m, 25 nsec/pulse

### **Portable Darkroom**

The tabletop film processor weighs 100 lbs. dry. It is easily transported and set up in the darkroom in one of the Vans listed below.

- AFP Imaging Mini-NDT Automatic Film Processor

### **Transportation**

The Van system was specially built for emergency response. They house the Schonberg linac, Co-60 source, 300 kVp x-ray, RTR image processing rack, and darkroom. The motor-generator sets have been used to provide power at remote locations for many other operations as well.

- Ford Econoline Vans specially modified, with 12 kW Onan Motor-Generators
  - Radiography Van
  - Darkroom Van
- Wells Cargo Trailer

### **Infrared Video**

The infrared video system has been used very little for NDT at Los Alamos. We have no qualified operators at the present time.

- Inframetrics Model 600 IR Video System, 3 - 14 micron bandpass, minimum detectable temperature difference 0.1°C, 256x200 resolution

### **Other portable NDT equipment**

- Panametrics 5052 Pulser/Receiver and Fluke 97 Scopemeter
- Panametrics Epoch II Ultrasonic Unit
- Krautkramer-Branson Thickness Gauge
- numerous ultrasonic transducers
- Zetec MIZ-20A Eddy Current Unit
- Staveley Nortec 19E Dual Frequency Eddy Current Unit
- Holiday Detector, high voltage spark generator
- DSA Acoustic Resonance Spectroscopy System

### **APPLICATIONS**

Listed here are several unclassified applications of portable NDT and dynamic diagnostic equipment Los Alamos has performed over the past several years.

#### **Accident Response**

The Los Alamos NDT unit maintains a transportable radiography capability for emergency response to weapons accidents as part of a larger Department of Energy Accident Response Group. We have recently constructed and delivered an upgraded version of this capability to Russia. The accident response systems include portable linacs, real-time radiography detection and image processing, darkroom facilities, and all necessary transportation and power to be self-sufficient in remote locations. (1986 - present) [1]

#### **Container Inspection**

Real-time radiography has been used at several sites around Los Alamos to scan waste drums to check their contents before movement. Of particular interest is the presence of free liquids within the containers. The Sperry 160 and 300 units have been the workhorses in this application. The linac has been used to do RTR on lead lined and concrete-encapsulated waste drums. We have also used RTR with the 300 kVp unit to verify the contents of containers of radioactive materials in storage. (1990 - present)

#### **Reactor Fuel Rod Safety Studies**

We have performed linac radiography several times on reactor fuel rods immediately after irradiation in a reactor at Sandia National Laboratories, Albuquerque, NM to determine the fuel condition in a reactor accident simulation. (1987 - present)

### **Nuclear Weapons Safety Studies**

Real-time radiography with the linac is used to observe high temperature reactions inside a furnace simulating accident conditions (fire) for nuclear weapons to determine alternative design safety factors for plutonium containment layers. We have done many runs of this experiment bringing the linac and RTR equipment into Los Alamos' Plutonium Facility. (1989 - present)

### **Rocket Motor Static Firing**

Real-time radiography with the linac and flash x-ray were implemented at Thiokol Corp., Brigham City, UT for observing the burn and slag buildup in two rocket motor static fire tests for the small ICBM program. An intensified SIT camera and two 14 in x 17 in. ZnCdS phosphor screens made up the RTR system. (1987 - 1988)

### **Missile Stage Separation Testing**

We performed a job at Hercules Aerospace in Magna, UT to determine if a redesigned missile separation ring was performing as expected to solve a problem with an earlier design. A unique imaging method was implemented using Xybion electronic cameras with continuous x-ray illumination (Philips 420 kVp) on to a phosphor screen to integrate the motion over a 100 usec interval after detonation. The furthest extent of the motions was the required data and the x-ray images provided the best data to qualify the new design. (1989 - 1990) [2]

### **Torpedo Propulsion System Testing**

Real-time radiography was used to determine the burn characteristics of Lithium combustors for torpedo propulsion for the Naval Ocean Systems Center, San Diego, CA. A standard x-ray image intensifier with Sperry 160 kV x-ray source was used. Flash x-ray was also performed at intervals during the burn. (1987 - 1989)

### **Automobile Crash Testing**

Very recently we have been working with a major US automobile manufacturer to test feasibility of applying various Los Alamos NDT and dynamic test technologies to crash testing diagnostics. Portable flash x-ray, and real-time radiography and high speed x-ray video with the portable linacs have all shown promise. We have also performed tests using the PIXY flash x-ray machine which again shows promise for increasing the diagnostic information gathered in crash tests. (1994)

### **Electron Beam Welding Development**

Flash x-ray was used to determine the weld cavity size and shape produced during the welding process as a function of welding energy. (1970) [3]

### **Casting Process Development**

Flash x-ray has been used to provide stop-action radiographs of molten metal flow and distribution in molds at several times during the pour. (1977)

### **Macrostatistical Hydrodynamic Experiments**

High speed x-ray video is used to record the rate of propagation of spheres through various optically opaque fluid suspensions to determine viscosity (1985 - present) [4]

### **Propellant Safety Studies**

Flash x-ray has been used at Hercules Magna, UT and Cumberland, MD facilities and Morton Thiokol in Brigham City, UT to do propellant safety studies. Radiographs of the impact of propellant slugs against a plate are made at several times during the impact. (1977 - 1989)

### **Payload Delivery**

High speed video was used to record the deployment of an antenna on a satellite system at Los Alamos. (1993)

High speed video was used to record the missile case separation and payload launch in a test at Los Alamos. (1991)

High speed video has been used to record the deployment of alternate aigbag systems. (1993)

### **Flash X-ray with Electronic Imaging**

A ballistics imaging system has been constructed and is in use at a Los Alamos test range at the New Mexico Institute of Mining and Technology, Socorro, NM. It consists of six flash x-ray sources illuminating a 0.5 m x 2.0 m fast phosphor screen. Six independently positioned and timed Hadland Photonics intensified still video cameras pick up images from any portion of the screen. All cameras can view the same area or be set to track an event across the screen. Images can be taken as close as 10 usec apart. (1989 - 1992) [5]



## SUMMARY

The Nondestructive Testing Unit at Los Alamos National Laboratory maintains a comprehensive set of portable NDT equipment. This equipment has been used over many years to perform several unique jobs. These jobs cover standard film radiography, real-time radiography, large area RTR radiography and visual recording of fast events - both stop-action and continuous imaging, and under a variety of field conditions.

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